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Sandia National Laboratories

Quarterly Highlights of Sandia's Photovoltaics Program

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HIGHLIGHTS OF SANDIA'S BALANCE-OF-SYSTEM PROGRAM

This volume of Sandia's Photovoltaic Highlights focuses on some of the major issues addressed by Sandia's balance-of-system (BOS) program, which concentrates on power electronics and application of batteries in photovoltaic systems. The goals of the program are to:

- *advance the reliability of photovoltaic electronic components to the levels achieved by more mature products,*
- *reduce the life-cycle cost of photovoltaic systems,*
- *remove barriers to implementing photovoltaics,*
- *assist component manufacturers and system integrators with the development of more reliable, cost-effective systems.*

The program includes both contracts with industry and laboratory evaluations. The in-house laboratory evaluations supplement the capability of photovoltaic component manufacturers by providing a test-bed that includes extensive measurement capability and realistic reproduction of equipment in field conditions, including complex loads, photovoltaic arrays, engine/generators, and batteries. Further testing support is obtained from laboratories at the Southeast and Southwest Region Experiment Station and private labs. Benchmarking of products is conducted to obtain product information. Contracts with the photovoltaic industry focus on improving system reliability and reducing life-cycle cost, including the development of quality programs, HALT™ (highly accelerated lifetime testing), quality audits at the contractors' facilities, and some product development. Information about the BOS work at Sandia is available on Sandia's WEB site (www.sandia.gov/pv).

The inverter test facility at Sandia National Laboratories.

Islanding of Multiple Grid-Tied Inverters

A section of a utility system containing both load and generation that has been disconnected from the rest of the utility is called an island. Utilities currently require photovoltaic inverters to disconnect when they are in an island because of reasons related to safety, protection of loads, and utility operation. During the summer of 1997, Sandia conducted a series of tests to investigate islanding of multiple inverters on a single 120-V ac circuit. It was found that for $Power_{generation}/Power_{load}$ ratios in the range of .8 to 1.2, the inverters frequently islanded for more than the 2 seconds (times > 30 seconds were observed) within which some utilities require the inverter to shut down. It was also observed that the presence of a transformer in the islanded circuit resulted in shorter islanding times (disconnect times of < .5 seconds) because the transformer required a nonlinear magnetizing current that most inverters could not supply.

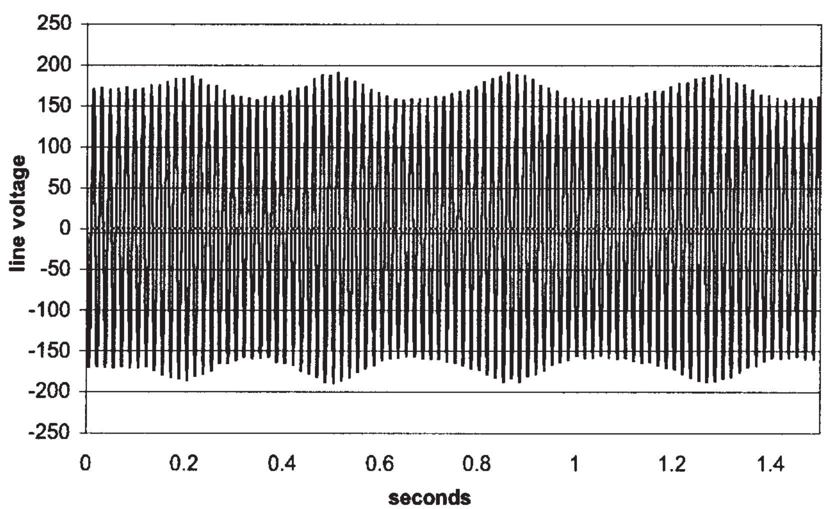
The conclusions drawn from these tests were

- multiple inverters on a single 120-V ac circuit were not disconnecting quickly enough,
- the presence of a distribution transformer resulted in quicker disconnect,
- future tests should include other than purely resistive loads so that worst-case islanding conditions could be determined,
- the use of multiple inverters utilizing different anti-islanding techniques increased islanding times.

Sandia initiated a working group composed of U.S. inverter manufacturers to address these issues and sponsored the development of a new approach through Ascension Technology, Inc. to prevent islanding. This method has been developed and tested; the results, titled "Results of Sandia National Laboratories Grid-Tied Inverter Testing" are on the Sandia WEB page (http://www.sandia.gov/pv) and were presented at the 2nd World Conference and Exhibition on Photovoltaic Solar Conversion in Vienna in 1998. The salient points of this work are the definition of a non-islanding inverter, an acceptable design to develop a non-islanding inverter, and the identification of a resonant RLC circuit as being a "worst case" test for islanding. A non-islanding inverter is defined as an inverter that does not island when the inverter output frequency is within the defined operating frequency and voltage ranges, and the Q (quality factor) of a connected resonant RLC load is less than 2.5. Typically in the U.S., the acceptable frequency range is from 59.5 to 60.5 Hz and the voltage range is from 106 V ac to 127 V ac. If the frequency is outside the defined frequency range, the RLC circuit can have any Q. The value of Q = 2.5 was selected because the input from utility engineers on the IEEE P929 (Recommended Practice for Utility Interface of Photovoltaic Systems) working group indicated that higher values of Q were unlikely on a utility distribution line.

A further requirement is that all inverters in parallel with the non-islanding inverter be also non-islanding and that no synchronous generators be present. A method for designing an anti-islanding inverter that includes combined passive and active techniques was included in the Vienna paper. The passive methods are over/under frequency and over/under voltage. The active methods are defined as SFS (Sandia frequency shift) and SVS (Sandia voltage shift). For the inverter developed during the course of this project, all of these methods were required to prevent islanding in a resonant RLC circuit with a Q of 2.5. Loads other than the RLC circuit disconnected very rapidly with the exception of an induction motor. Although the case with the induction motor did not disconnect as rapidly as the cases in which the loads were not tuned to 60-Hz, the motor load was slightly easier to disconnect from than a resonant RLC circuit with a high Q.

When manufacturers develop new grid-tied inverters, it is inconvenient to require a multiple inverter test to verify non-islanding inverters. Furthermore, Underwriters Laboratories, which plans to perform anti-islanding tests as part of its UL1741 inverter test procedure, desires a single inverter test. Therefore, Sandia is currently working on the development of a single inverter test that identifies an "islanding" inverter. In addition, Sandia is preparing a report that documents a procedure for evaluating multiple inverters. When IEEE P929 becomes a standard, it is likely that a single inverter UL test will be required and that Sandia's multiple inverter work will be referenced. Utilities feeling uncomfortable with the UL single-inverter test may either conduct their own multiple inverter tests or refer to Sandia's multiple-inverter evaluations. Work in 1999 will include multiple-inverter testing of several new inverters, each of which will be evaluated alone and with other inverters. At this time, it appears that any inverter that will island in the multiple-inverter scenario will also island by itself with a high Q resonant RLC load. This is demonstrated by the waveform shown below, where the utility disconnects at .1 second and the inverter runs on indefinitely.



Islanding of a Single Inverter Worst Case Load, RLC circuit, Q = 7.7.

Development of a New Hybrid 30-kW Power-Processing Unit

Some large hybrid power-processing units (PPUs) have experienced reliability problems, which may be attributed to their unique, site-specific designs. With that in mind, a specification was developed jointly between Sandia and Trace Technologies for a replicable design of a 30-kW hybrid power processor as a first step toward standardization. The PPU was to be tested at Sandia and provided to Arizona Public Service (APS) for use in its STAR facility. At STAR, it is to be integrated with a bank of tubular gel batteries of a new type that has been developed jointly by Yuasa and Sandia's battery group specifically for hybrid applications. The objectives of the project were 1) to assist in the development of reliable photovoltaic-hybrid power-processing products with widespread applications, 2) to provide APS with a useful tool for its application-driven research, and 3) to enhance understanding of hybrid power-processing issues.

Many of the observed problems in past installations resulted from the approach to site development. That approach assumed that the PPUs existed for the intended application, but then defined a specification that required a new product, and, consequently, fielded an untried prototype. The preferred approach, used in this development, includes the following steps:

1. define system requirements for a wide range of applications,
2. define inverter specification for a universal design,
3. build and evaluate an alpha unit,
4. field the unit at a test site, and, finally,
5. go to the production stage.

The key point is that development and evaluation be completed prior to field deployment. The objective is to prevent deployment of a new, under-tested, prototype in a field installation. This product is now being deployed at other sites.

Testing: During the course of testing at Sandia, several issues were identified. All were addressed by Trace Technologies in a cooperative, cost-sharing effort. The major modifications primarily involved the control system and were made in response to suggestions by Sandia and APS personnel. These modifications have an impact on system reliability, generator compatibility, battery maintenance, and/or user satisfaction. They should make the PPU more universally applicable and less site-specific so that it can be applied in various sites with minimal field interaction required from the design engineer.

Lessons Learned: Reliability is a critical concern of APS. From the perspective of a utility, the number of conditions that could result in a loss of load should be minimized.

Another lesson learned is that if ac current limiting is used to protect the PPU, then voltage sags are inevitable when large loads are applied. To minimize such sags, a reduced-voltage starter should be considered for motors that are a significant fraction of the PPU rating. Installation of such relatively inexpensive equipment can enhance performance significantly and should be considered a routine part of site load management when installing a photovoltaic-hybrid system. Site loads should be assessed for their sensitivity to disturbances and, if necessary, protected with an uninterruptible power supply.

Selection of an undersized or poorly regulated engine/generator can undermine system performance. Engine/generators for photovoltaic-hybrid systems should include modern electronic (isochrynous) governors and should be rated for the maximum "expected" site load.

Batteries in Hybrid Systems

Battery treatment is a key factor in the reliability and life-cycle cost of a hybrid system. As such, the charging algorithm should provide

1. user-adjustable voltage and time set points for both normal and finish-charge,
2. temperature compensation,
3. battery over-temperature protection, and
4. automatic finish-charge.

Battery temperature compensation is important for ensuring the battery is properly charged. Lowering the charge voltage avoids overcharging when the battery is hot. Conversely, raising the battery charge voltage avoids undercharging when the battery is cold. However, temperature compensation has limits. The battery manufacturer's specifications should be consulted.

Additional Work: Three issues related to battery treatment were discussed at a pre-installation kickoff meeting for the STAR project that included representatives of Sandia, APS, Arizona Sate University, and Yuasa.
The issues are

1. truncating temperature compensation outside a selectable range of battery voltages
2. addition of a separate set point for the taper value of finish-charge current
3. addition of a "time at battery voltage" set point to avoid unnecessary generator starts due to large short-duration loads such as motor starts.

Trace Technologies is evaluating the impact and the level of risk associated with implementation of these refinements. System performance at APS is being monitored by a data-acquisition system developed by the Southwest Technology Development Institute and operated and maintained by Arizona State University.

Sandia's Quality/Reliability Program Results in Improved Reliability

Accelerated lifetime testing of photovoltaic electronics: Highly accelerated lifetime testing (HALT™) is an effective tool for increasing reliability. By identifying latent problems, HALT™ lowers the failure rate from that typically associated with new products to that of a mature product. This evaluation stresses products beyond design specifications, establishes destruct limits, determines the root cause for failures and corrects problems before a product is fielded. Sandia is acting as a facilitator between the photovoltaic manufacturers and highly accelerated test laboratories (such as QualMark), which provide this testing.

A typical test on a small inverter or charge controller costs $11,000, takes 200 hours for a humidity test and about 30 hours for vibration, temperature, and electrical stresses. Products in the development stage are targeted for HALT™ testing.

Quality and Reliability Contracts: Sandia has initiated contracts with selected companies to install quality programs at the contractor facilities that can lead to ISO 9000 certification. These programs are leading to more robust balance-of-system components.

Quality audits at contractor facilities: In lieu of funding full-scale quality programs at the contractors' facilities, a quality audit can be provided by Sandia. The quality audit consists of a visit by a quality inspector who then provides a written list of problem areas and suggested improvements. Quality audits are provided to qualified contractors who request them.

Sandia's Testing/Benchmarking Activities

Filling a continuing need, the evaluation laboratory at Sandia supports PVMaT, photovoltaic manufacturers, and the photovoltaic industry. It includes instrumentation, loads, and power sources that may be beyond the means of balance-of-system manufacturers. Evaluations are provided free of cost to most U.S. manufacturers of photovoltaic components. As well as supporting the development of new products, the laboratory facilities benchmark existing products. These evaluations include:

- Evaluations of small, grid-tied inverters for islanding, power quality, and response to power disturbances, including voltage sags, surges, and EMI pulses while the inverters are connected in parallel with other inverters.
- Benchmarking evaluations of inverters that identify inverter problems or result in a report posted on the WEB. These are products that are generally not the result of a government contract and are available to the public for purchase. The tests of four such inverters in the past year resulted in redesign of the inverters and no report for the WEB. One evaluation of a product led to a WEB report.
- Evaluations of PVMaT hardware. When delivered to Sandia, PVMaT prototypes undergo a rigorous characterization. This is generally the first real evaluation of these prototypes, and design changes invariably result from this evaluation. Correcting problems and retest are essential elements in the development of any new product. Frequently, however, the contract is near its end and the contractor has not allotted funding for more product changes.
- Prototypes and other developmental photovoltaic balance-of-system hardware. These evaluations typically result from a manufacturer's request.

Battery Evaluations for Hybrid Photovoltaic Systems

Sandia and the Florida Solar Energy Center (FSEC) are now using their extensive experience with small stand-alone photovoltaic battery testing to address new work related to photovoltaic-hybrid battery testing. Photovoltaic-hybrids represent a relatively large group of renewable energy power systems with multiple power sources that vary considerably with respect to system design, size, load characteristics, and possible battery management strategies. Preliminary test results at Sandia indicate that both flooded and valve-regulated lead-acid (VRLA) batteries can quickly lose capacity in a photovoltaic-hybrid environment. This premature capacity loss stems primarily from an operational mode known as deficit-charge cycling. Deficit-charge cycling occurs when a discharged battery is not fully recharged after each discharge. This is a common occurrence that results from cost-reduction practices that resulted from the high cost of sizing the photovoltaic array to fully recharge the battery or the added engine/generator runtime required to finish-charge the battery. Work at Sandia is now focusing on identifying the minimum hybrid battery-charging requirements to prevent premature capacity loss resulting in a shortened battery cycle-life. The goal of this work is to minimize operation and life-cycle costs in photovoltaic-hybrid systems.

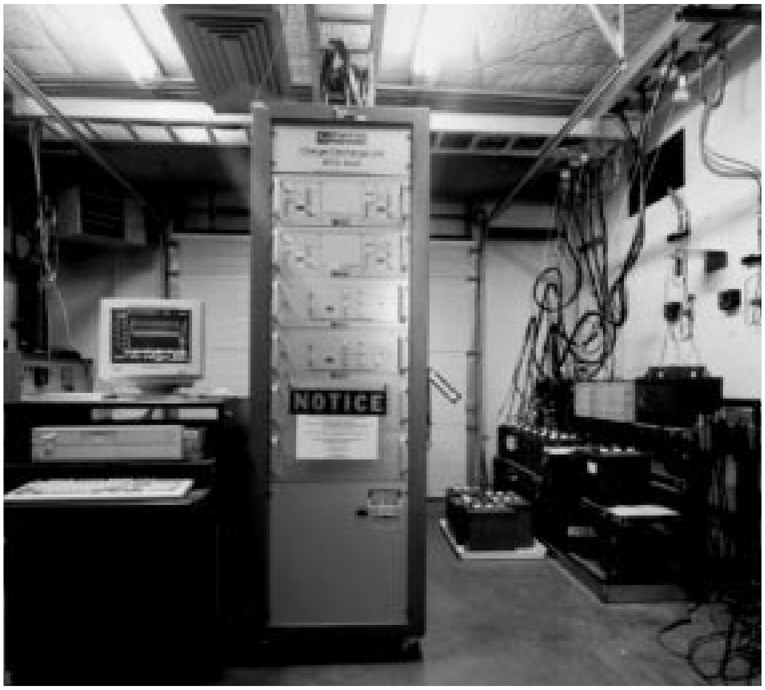
A photovoltaic array and/or engine/generator can charge batteries in photovoltaic-hybrid systems in a variety of configurations. Multiple power sources provide more system design flexibility and improved availability, but they also increase complexity. With complexity come more uncertainties with respect to system design and management of that design. Since there can be a wide variation of power contributed by the photovoltaic array or other power sources, it is possible to design photovoltaic-hybrid systems that are almost totally dependent on the engine/generator for battery charging or systems that are essentially stand-alone photovoltaic systems with the engine/generator used only as an emergency power source. Battery-charging requirements and the necessary controls will vary considerably as the dependence on the engine/generator varies. Batteries in photovoltaic-hybrids may also be subjected to more abusive conditions than in stand-alone photovoltaic systems if the system design does not provide the necessary controls. An engine/generator does not guarantee proper battery charging. With this in mind, laboratory testing is now under way to identify appropriate deficit-charge cycle periods, finish-charge ("equalization") times, regulation voltages, and time intervals between finish-charges ("equalization") for flooded and VRLA deep-cycle batteries. It should be noted that battery equalization in photovoltaic-hybrid systems is frequently used interchangeably with battery finish-charge. Equalization is a distinct process that begins at the end of the finish-charge for the express purpose of bringing all cells in a battery string to equal voltage or capacity.

Preliminary Test Results: Traditional lead-acid battery cycle test results to rate photovoltaic battery performance can be significantly skewed toward the positive by using high charge/discharge rates. Most battery testing by battery manufacturers and others, including Sandia, has used test procedures that more rapidly cycle the battery than it would normally see in a photovoltaic-hybrid system. The more rapid 10-hr or less cycle rates commonly used by most laboratories are not typically characteristic of photovoltaic-hybrids. Photovoltaic-hybrids will more commonly see charge and discharge rates of 20 to 100 hours. Cycling at the slower rates promotes hard sulfation and premature capacity loss due to the extended time spent in a discharged condition and the resulting deeper cycles. Thus battery recovery at low rates can be much more difficult and cycle-life can be less than expected. Therefore, the test results reported here may not be consistent with either manufacturers' or other laboratory testing, since those tests are generally performed at high rates and the tests reported on here were performed at lower rates. It is always important that the test procedure duplicate the battery application as closely as possible because of these performance differences.

Test results at Sandia's Photovoltaic System Applications Department have shown that the deficit-charge cycle time and full recovery requirements are significantly different for flooded (vented) and VRLA batteries; therefore, it is critical to understand the specific charging requirements of the battery used in the photovoltaic-hybrid system. Vented batteries that spend more than a few days in a deficit-charge condition will begin to suffer from electrolyte stratification. Stratification makes recharge more difficult by prematurely raising battery voltage during recharge. This condition falsely indicates a higher battery state-of-charge than is actually present. In addition to stratification in vented batteries, the charge efficiency of both vented and VRLA batteries needs to be accounted for by charging more amp-hours (Ah) into the battery than were removed during each cycle. The Ah overcharge requirement for a fully discharged vented battery is usually between 120 and 130%. VRLA batteries usually require between 105 and 112% overcharge. The combination of renewable energy power sources and engine/generator battery charging must meet the overcharge requirement to compensate for the losses in battery charging. Because charge efficiency is a non-linear inverse function of battery state-of-charge, with efficiency being very high at low states-of-charge and less than 50% at high states-of-charge, generic overcharge statements should be tempered with the knowledge that battery charge efficiency is highly dependent on the battery depth-of-discharge regularly experienced.

In all cases, photovoltaic-hybrids need to bedesigned to minimize deficit-charge cycling while still minimizing engine/generator run time. This can be accomplished by using appropriate regulation voltages and providing no more than the minimum required finish-charge intervals. If the photovoltaic and/or engine/generator charge controller regulation voltage is too low, or the time at regulation voltage is too short, then the required battery overcharge cannot be achieved effectively with either the photovoltaics or engine/generator. Proper battery management requires a photovoltaic or engine/generator charge controller with an appropriate photovoltaic regulation voltage, adequate time at regulation voltage, and a temperature compensated regulation voltage. A key element in achieving this is an engine/generator battery charge-control strategy that provides a bulk charge function that initiates on low voltage and terminates on voltage and time, and an automatic battery finish-charge at set intervals from one to four weeks for specified finish-charge times and voltages.

As an example of this work, two VRLA batteries, one gelled electrolyte and one absorbed glass mat, are being tested in the laboratory to identify appropriate deficit-charge intervals and finish-charge requirements. Follow-up field tests will be conducted to further validate the findings. However, since these preliminary results are important, they are being released at this time.

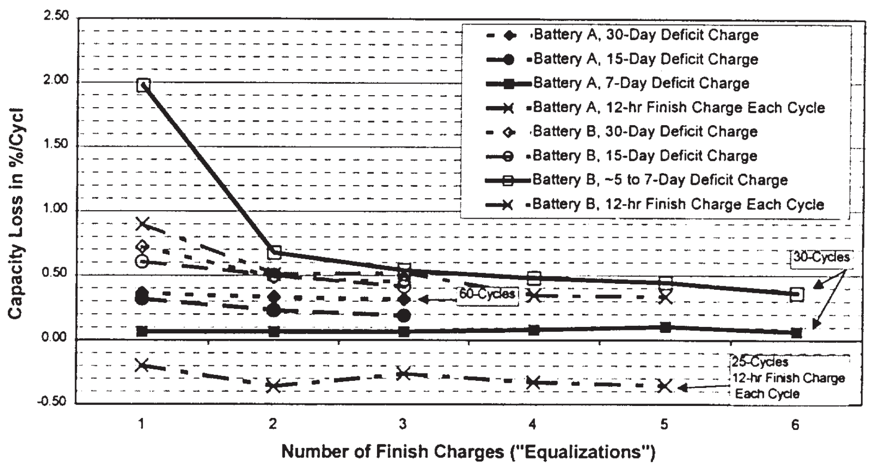


The battery test facility at Sandia National Laboratories.

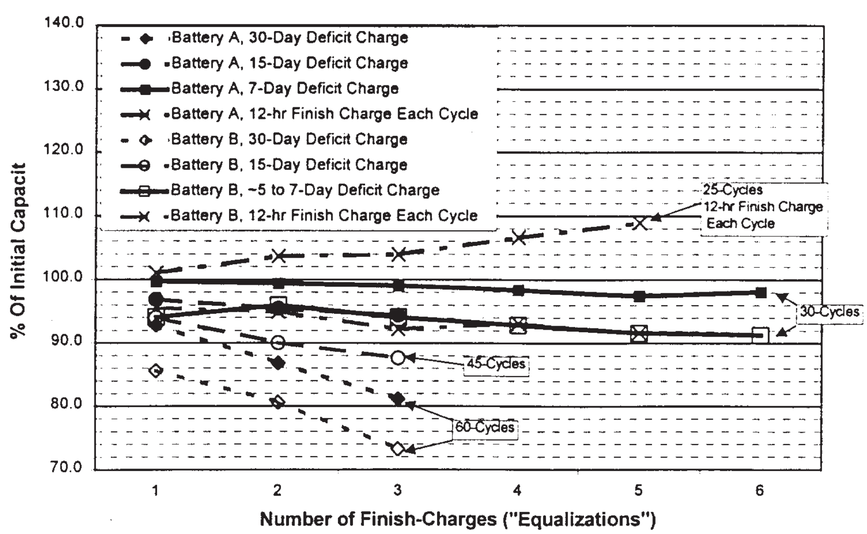
Laboratory testing at a 24-hr charge and 35-hr discharge rate to 1.98 Vpc (11.88 volts), a ~65% depth of discharge, has shown that both Batteries A and B can lose capacity quickly after short periods in deficit-charge cycling. As shown in Graphs 1 & 2, Battery A lost 19% and Battery B lost 27% of its available capacity to 1.98 Vpc after three 30-day deficit-charge cycle intervals. In both cases the battery was bulk charged to 2.35 Vpc (14.1 volts) from 1.98 Vpc (11.88 volts) every 1.5-days, then finish-charged at 2.35 Vpc (14.1 volts) for 12-hours every 30-days.

Graph 1 showing premature available capacity loss to 1.98 Vpc after each finish-charge indicates that Battery A lost 0.31, 0.19, 0.06, and -0.30% per cycle for the third 30-, 15-, 7.5- and 1.5-day deficit-charge interval. Battery B initially lost 2% per cycle after the first 3-cycle 5-day deficit charge interval. After the second and third deficit charge intervals, the capacity loss stabilized to between 0.68 and 0.41% per cycle for all deficit charge intervals including the 1.5-day interval. The graph indicates that both batteries experience less capacity loss with each succeeding deficit charge interval and this may eventually result in a stable capacity, but not without significant initial capacity loss. Battery A clearly demonstrates a capacity gain with the 1.5-day deficit-charge interval to only a small capacity loss (-0.3 to 0.06%/cycle) with the 7.5-day deficit charge interval. Battery B, with a much higher capacity loss rate at all deficit charge intervals (~0.41%/cycle), does not clearly show a reduction in capacity loss due to more frequent finish-charges at less than 15-day intervals.

Graph 2 showing the percent of initial capacity as a function of the number of finish-charge intervals indicates that after the third 30-day deficit-charge interval Batteries A and B quickly lost capacity to 81% and 73% of their original value. With more frequent finish-charges of 15, 7.5, and 1.5 days, Batteries A/B measured 95/88, 99/94, and 104/92% of their initial capacity. Battery A shows that it can almost maintain or even gain capacity with 7.5- to 1.5-day finish-charges, but Battery B consistently lost capacity at all finish-charge intervals, indicating that it had an insufficient finish charge.



Graph 1. VRLA battery capacity loss vs. length of deficit-charge interval.



Graph 2. VRLA battery capacity loss vs. length of deficit-charge interval.

The above test results are important in defining battery charging requirements and predicting expected cycle-life for the above test conditions. The test results indicate that battery performance would probably be significantly better for Battery A if finish-charged every week. The clear performance improvement for weekly finish-charges is not apparent for Battery B, but at finish-charge intervals of 15 days vs. 30 days the capacity loss is significantly less. It is generally accepted that less capacity loss will promote improved battery cycle-life. Certainly the traditional thinking that either no finish-charges were required or that 30-day intervals between finish-charges ("equalization") were acceptable for all VRLA batteries has been shown to be incorrect for photovoltaic-hybrid applications using a similar cycle.

Summary: Battery management in photovoltaic-hybrid systems needs to follow a few simple rules even though the system design can vary considerably. If the system designer provides the photovoltaic battery with its basic charging needs on a regular basis, then the traditional photovoltaic battery problem of premature capacity loss and early cycle-life failure can be minimized. Maintaining photovoltaic batteries in a healthy condition in many cases will more than double cycle-life and thus increase reliability, thereby significantly reducing overall life-cycle costs. Unfortunately, all the information required to do this is not always available. Sandia's photovoltaic balance-of-system group is working with battery manufacturers to provide the missing information.

Proper Battery Charging of Photovoltaic-Hybrids: Any photovoltaic-hybrid battery-management strategy should limit the number of days the battery spends in a deficit-charge condition and should provide a means for full recovery of that battery.

*[For more information about this report, please contact **Russ Bonn**, (power electronics) 505-844-6710, rhbonn@sandia.gov or **Tom Hund**, (charge controllers & batteries) 505-844-8627, tdhund@sandia.gov]*

BRIEFS

Renew the Government in publication

The fourth report in the popular "Renew" series is being printed and will be available in January 1999. *Renew the Government: Summary of Projects and Lessons Learned* was prepared by staff in Sandia's Photovoltaic Systems Assistance Center in collaboration with the Bureau of Land Management, National Park Service, and the U.S. Department of Agriculture (USDA) Forest Service. The partnership between Sandia, the Department of Energy, and these government agencies began in the early 1990s with the goal of establishing sustainable use of photovoltaic technology in those agencies, and it resulted in benchmarks being established for assessments of applications and acceptance of photovoltaics within each agency. Based on the results of earlier assessments, more than 120 new projects were developed and installed; and the new report documents these projects as well as lessons learned through partnership work.

The majority of projects highlighted in *Renew the Government* are for facility power, lighting, and water pumping. The report contains project data sheets with general information on system components, as well as photos for each of the systems. The projects are cross-referenced by agency and application in an appendix.

To obtain a copy of *Renew the Government*, please send an e-mail request to *pvsac@sandia.gov* asking for the report by name, and including pertinent mailing information. It can also be ordered through Sandia's WEB site for photovoltaics: *www.sandia.gov/pv.*

[For technical information about the program, please contact **Hal Post,** *hnpost@sandia.gov]*

New on Sandia's WEB site

If you haven't visited Sandia's photovoltaics WEB site recently, there are several new additions. Please visit *www.sandia.gov/pv*

Most of our technical reports are now available online and downloadable in their original format. These now include *Water Pumping, Renew the Parks, Evaluating PV, PV Systems for Utilities, PV for Development Applications, Guidelines for Livestock Water Pumping,* two documents on Interconnection issues, and the very popular *Photovoltaic Power Systems and the National Electrical Code: Suggested Practices. Renew the Government,* Sandia's newest publication, is also available online.

Technical papers presented in September at the National Center for Photovoltaics' Program Review Meeting are included on the site. The following papers may be found under their topical areas:

- Gee, James, et al. *Back-Contact Crystalline-Silicon Solar Cells and Modules.*
- King, David, et al. *Photovoltaic Module Performance and Durability Following Long-Term Field Exposure.*
- Ruby, Doug, et al. *Plasma Etching Texturing, and Passivation of Silicon Solar Cells.*
- Bonn, Russell, et al. *Sandia National Laboratories Photovoltaic Balance of Systems Program.*
- Rosenthal, Andy. *Performance and Economics of the PV Hybrid Power System at Dangling Rope Marina, Utah.*

Sandia's photovoltaics WEB site has climbed to become the 4th most accessed directory at Sandia, with over 70,000 hits last month. And the technical papers and Quarterly Highlights posted there continue to be among the most frequently downloaded files at Sandia.

Historically, the photovoltaics departments have made available more than 10,000 hard copy technical documents annually to suppliers, manufacturers, designers, government agencies, and interested individuals. The WEB site now has all of its photovoltaics publications online, making this information available to more people—U.S. industry members and others—easier, quicker, and less expensively.

BP Solar distributors visit Sandia

Approximately 40 BP Solar senior management, staff, and national distributors spent a day touring Sandia's photovoltaics facilities and hearing presentations on the labs' capabilities. Likewise, Sandians were briefed on BP's company structure and activities. Presentations were made on Sandia's work in systems, balance-of-systems, modules, batteries, and our Mexico photovoltaics work, followed by a tour of three laboratories and the solar power tower.

Peter Beadle, president of BP Solar America, was among those in attendance. Beadle and other BP representatives felt the visit was very worthwhile. Contacts made and opportunities discussed at such briefings are instructive for all concerned and help further collaborative efforts.

[Other companies interested in participating in meetings such as this should contact **Connie Brooks** *in Sandia's Photovoltaics Program, cjbrook@sandia.gov, (505) 844-4383.]*

Utility-interconnect issues discussed with Japanese

Officials from the Japan Electric Safety and Environment Technology Laboratories (JET) visited Sandia to discuss utility-interconnect issues for photovoltaic power systems. The primary objective of their visit was to share Japan's current technical requirements for interconnection and their hardware certification guidelines. The visitors were Shigeyoshi Takekoshi, Deputy Director, Research, JET; Shoichi Suinaga, Manager, Research, JET; and Shoji Fujukawa of the New Energy and Industrial Technology Development Organization (NEDO).

In sharing ideas about interconnecting and certifying inverters and their reliability and other electronic hardware for photovoltaic applications, the visitors provided the new Japanese Guideline of Technical Requirements for Grid-Interconnection of PV Systems. The Japanese grid-interconnecting guideline was written to cover all grid-interconnection equipment, whereas the U.S. is focusing on the National Electrical Code, IEEE interconnect standards, and listing standards for photovoltaic systems. Japanese anti-islanding requirements appear to be easing and converging on requirements similar to those in the U.S. Reciprocity or sharing of UL standards will serve to bring interconnect requirements together.

The Japanese also brought an outline of Certifications for Interconnect Devices and Inverters. Note that the Japanese certification document covers almost all interconnection devices, whereas the U.S. uses standards for each category. New Japanese efforts were discussed that parallel the new IEEE 929 interconnect guideline and standards similar to the UL 1741 standard for inverters. In addition to the primary objective of sharing technical requirements, the visitors inquired about methods for determining hardware reliability and mentioned that Japan was planning to establish a hardware reliability test laboratory for inverters and balance-of-system hardware. The visit to Sandia followed visits to two Underwriters Laboratories' facilities to discuss collaboration for listing of photovoltaic power processing equipment. The visitors were given tours of the inverter and module test facilities and the 5 MW solar power tower.

[For more information, please contact ***Ward Bower*** *(505) 844-5206, wibower@sandia.gov]*

International Energy Agency Task V begins three-year extension

The International Energy Agency (IEA) is beginning a five-year extension of the Implementing Agreement for a Cooperative Program on Photovoltaic Power Systems. As part of that extension, Task V, Grid Interconnection of Building Integrated and Other Dispersed Photovoltaic Power Systems, is embarking on a three-year extension of its work. The Task V work has been modified to include high penetrations of photovoltaics into utility grid networks.

The 11th meeting of the Task V Experts group was held in September to culminate the first five years effort and to initiate work for a three-year extension of Task V work. Significant new work includes collaborative international studies on high penetration of photovoltaic systems into a utility grid, and collaboration with the IEA Task 7 to address technical issues associated with building-integrated photovoltaic installations. The first of two new Task V reports will be the results of addressing photovoltaic interconnect issues, entitled Utility Aspects of Grid-connected Photovoltaic Systems. The second will be a summary report of the first five years of work. Both will be available to the U.S. photovoltaics industry on completion.

Sandia hosted the first meeting of the Task V extension. Guest speakers included Roger Hill, Sandia, to review the Public Service Company of New Mexico proposals for 5 MW of renewable installations; Steven Strong, Solar Design Associates and U.S. Task 7 expert, to review the new Task 7 Photovoltaic Power Systems in the Built Environment; Robert Hassett, DOE/HQ, to review the national photovoltaics program; Chris Cameron, Sandia, to review Sandia's energy program; and John Stevens, Sandia, to review the new IEEE 929 utility interconnect guidelines. Technical tours included Sandia's solar thermal and solar photovoltaic test facilities and local photovoltaics installations, including one of Solarex's Photovoltaics Value systems.

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Sandia creates and distributes a variety of publications on photovoltaic systems and their applications. For a list of these documents, please contact the Photovoltaic Systems Assistance Center:

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